Energy Consumption Series

Lighting in Commercial Buildings

March 1992

Energy Information Administration
Office of Energy Markets and End Use
U.S. Department of Energy
Washington, DC 20585

Contacts

This report was prepared under the direction of W. Calvin Kilgore, Director of the Office of Energy Markets and End Use (202/586-1617), and Lynda T. Carlson, Director of the Energy End Use and Integrated Statistics Division (EEUISD) (202/586-1112). Specific information regarding the contents or preparation of this publication can be obtained from Dwight K. French, Chief of the Transportation and Industrial Branch (202/586-1126). Questions regarding the Commercial Buildings Energy Consumption Survey may be referred to Martha M. Johnson, Survey Manager (202/586-1135).

Detailed technical questions may be referred to the following members of EEUISD:

Miriam L. Goldberg	Principal Author	202/586-1129
Jennifer A. Wolfe	Data Analysis Graphics Report preparation	202/586-5736
Hattie Ramseur	Publications Report production	202/586-1124

Preface

This report, *Lighting in Commercial Buildings*, inaugurates a new analytic series. Extensive information on sectoral energy consumption is collected by the Energy Information Administration (EIA). Almost all of the information is available in statistical publications and public use diskettes. The EIA has initiated a systematic effort to analyze this information to explain what has been happening in energy consumption and efficiency in the energy-consuming sectors. One component of this effort is that each of the energy consumption statistical publications will attempt to incorporate more analysis of the data presented in these reports. A second component, and perhaps most important, the "Energy Consumption Series" will highlight various analyses of the data and the data developmental activities that have provided insights into understanding issues, energy usage, and efficiency in each sector.

This first publication in this series uses EIA's Commercial Buildings Energy Consumption Survey as a basis for analyzing lighting in commercial buildings. This analysis follows on the work undertaken by the EIA in support of the National Energy Strategy.

Feedback from users is critical for continuing improvements in the energy consumption information EIA provides.

If you have any comments and/or suggestions on this new series, or on this report in particular, please contact Miriam L. Goldberg, Team Leader, Analytic Data Bases at:

U.S. Department of Energy
EI-632, Mail Stop 2G-090
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Phone: (202) 586-1129 Fax: (202) 586-0018

Contents

Tables

Illustrations

Executive Summary

Lighting represents a substantial fraction of commercial electricity consumption. A wide range of initiatives in the Department of Energy's (DOE) National Energy Strategy have focused on commercial lighting as a potential source of energy conservation. This report provides a statistical profile of commercial lighting, to examine the potential for lighting energy conservation in commercial buildings. The principal conclusion from this analysis is that energy use for lighting could be reduced by as much as a factor of four using currently available technology.

The analysis is based primarily on the Energy Information Administration's (E1A) 1986 Commercial Buildings Energy Consumption Survey (CBECS). The more recent 1989 survey had less detail on lighting, for budget reasons. While changes have occurred in the commercial building stock since 1986, the relationships identified by this analysis are expected to remain generally valid. In addition, the analytic approach developed here can be applied to the data that will be collected in the 1992 CBECS.

Lighting Energy Conservation Potential

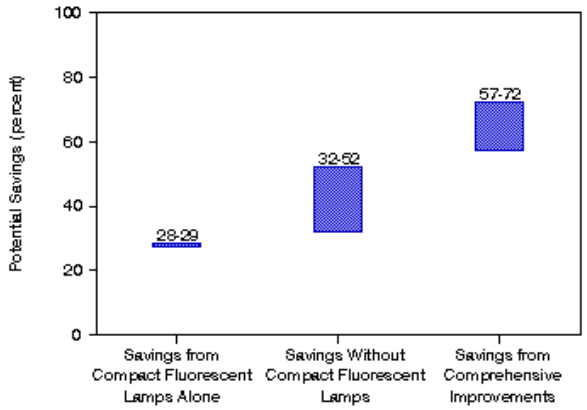
Substantial energy savings are possible using more efficient commercial lighting equipment and practice. Estimates of the poten savings depend heavily on assumptions regarding the types of lamps and fixtures to be replaced, the effectiveness of various lighting conservation measures, and how strong a lighting level is to be maintained. The savings estimates under various assumptions span a wide range, from under 30 percent to nearly 80 percent of current use (Figure ES1).

 # Savings from Compact Fluorescent Lamps: *Converting all incandescent bulbs (the typical screw-in type) to compact fluorescent lamps with reflectors is estimated to save close to 30 percent of current (1986) energy use for commercial Lighting.*

 # Savings Without Compact Fluorescent Lamps: *Even greater savings can be achieved without using any compact fluorescents, but converting all lamps and fixtures to the most efficient version of the same type (fluorescent, high-intensity discharge, or incandescent), together with lighting control to devices.*

 # Savings from Comprehensive Improvements: *Universal replacement of lamps and fixtures by more efficient equivalents, together with lighting controls, could save as much as 72 percent of current commercial lighting energy use. The replacements for this case include the best of the previous two cases. If, in addition, lighting levels are reduced by 25 percent, the total savings could reach nearly 80 percent.*

Figure ES1. Range of Potential Savings, Maintaining Current Lighting Levels



Note: Each shaded band indicates the range of savings estimates obtained, under varying assumptions for the effectiveness of the conservation features considered for each case. The potential savings are shown for each case as a percent of the base case lighting energy estimate (321 billion kilowatthours). Additional savings are possible if lighting levels are reduced.

Sources: Adapted from Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871A, "Building Questionnaire" of the 1986 Nonresidential Buildings Energy Consumption Survey; and sources described in Appendices B and C.

The savings analysis spans a range of plausible assumptions. Nonetheless, other modifications to equipment and, practice could be considered, and other assumptions for the effectiveness of these might be more appropriate. This report presents a framework that allows alternate savings estimates under alternate assumptions.

These savings estimates are based on the use of current commercially available technologies and assume that all lights of a given type are replaced immediately. Actual replacements would, of course, occur over time as the new lighting equipment penetrates the marketplace and associated costs are reduced as the technology improves. Indeed, in all likelihood some of the potential savings have already been achieved, through increased penetration of energy-efficient equipment since the time of the survey the analysis is based on. Thus, the savings estimates are provided only to describe the potential for savings and are not a prediction of the level of savings that will be realized in the marketplace.

Commercial Lighting Energy Profile

The potential for commercial lighting energy conservation is derived from a statistical profile developed in this report of commercial lighting energy. This profile reveals important relationships among lighting energy use and building characteristics including activity, building size, operating hours, and lighting equipment.

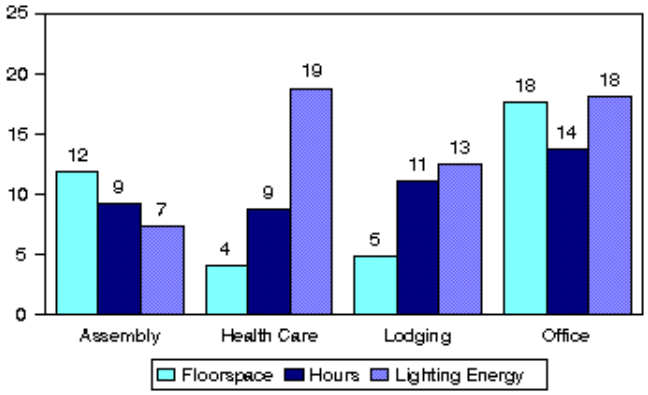
Lighting Energy: *Energy used for lighting in commercial buildings is on the order of 1 quadrillion Btu, 40 to 50 percent of commercial electricity use for 1986. On a per floorspace basis, energy use for lighting is estimated to be around 6 kWh per square foot.*

Lighting Equipment: *Incandescent bulbs serve only 19 percent of the lighted commercial floorspace, but account for 37 percent of commercial lighting energy consumption. Substantial energy could be saved by converting space lighted by incandescent bulbs to more efficient lighting equipment.*

Efficient Equipment: *Buildings with greater lighting needs tend to have more efficient equipment. Higher lighting levels and longer hours represent greater lighting needs.*

Building Activity: *Health care and lodging buildings account for relatively high proportions of commercial lighting energy use compared to their floorspace (Figure ES2). Both these buildings types tend to have long hours of use. Health care buildings also have high lighting levels. Lodging buildings tend to have a high proportion of space served by incandescent bulbs, which are relatively inefficient.*

Figure ES2. Lighting Service Measures by Selected Building Activity

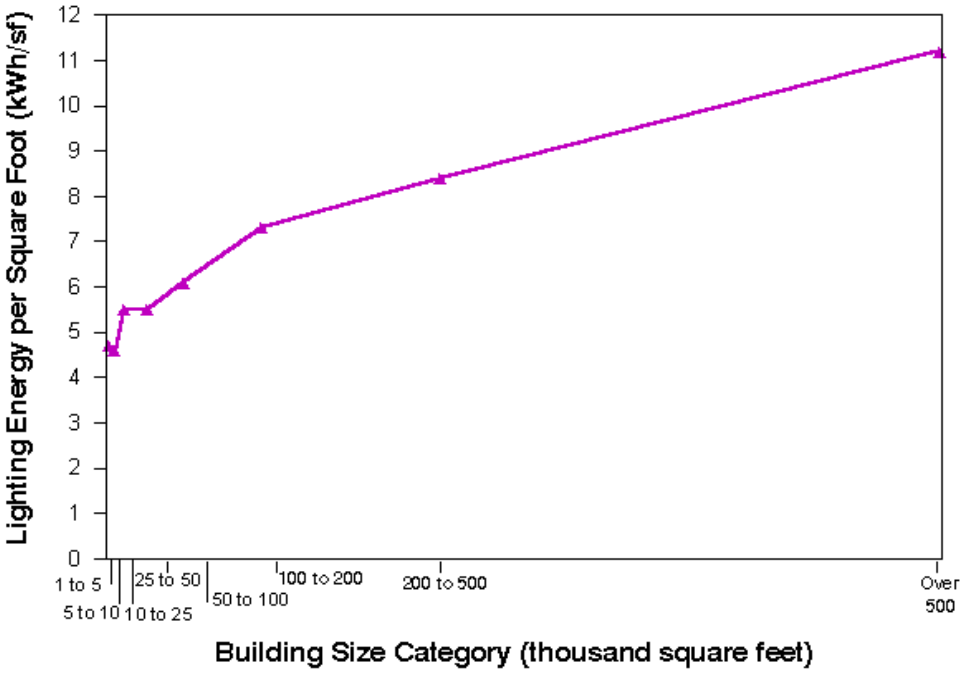


Note: For each principal building activity, the percents are the estimated amounts for the activity as percentages of the total commercial lighted floorspace (49.59 billion square feet), lighted floorspace-hours (3.5 trillion square foot-hours), and lighting energy (321.4 billion kilowatthours).

Sources: Derived from Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871 A, "Building Questionnaire" of the 1986 Nonresidential Buildings Energy *Consumption Survey*.

Building Size: *Larger buildings tend to have higher lighting energy use per square foot (Figure ES3).* The higher energy use is related to longer operating hours and activities associated with higher lighting levels. The effects of longer and stronger lighting use are somewhat mitigated by the use of more efficient equipment in larger buildings.

Figure ES3. Lighting Energy per Square Foot by Building Size Category



Note: • Average quantities for each size category are plotted at a horizontal position corresponding to the average size for buildings in that category.

Source: Derived from Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871A, "Building Questionnaire" of the 1986 Nonresidential Buildings Energy Consumption Survey.

Data and Research Needs

This study was performed using the 1986 CBECS data, because the more recent 1989 CBECS had less detail on lighting equipment and conservation features. Extending the methods used here to other survey years would therefore require further assumptions and approximations. However, more detailed lighting questions will be restored for the 1992 cycle. The analysis can be repeated directly with the more up-to-date data when they become available. In addition, the 1992 CBECS sample will be a revisit to the 1986 sample, allowing longitudinal comparisons over the past six years.

Several extensions to this analysis could be made. One would be to reconcile the energy estimates with total building electricity consumption. Another would be to incorporate assumptions about the degradation of equipment efficiency over time. The CBECS data also contain complete weekly operating schedules; together with the estimates obtained here for in-use lighting power densities, these schedules could serve as the basis for estimation of lighting load shapes.

Additionally, the results developed here can be combined with economic equipment assessments to provide estimates of the costs associated with the conservation strategies. As part of the Lighting Initiative sponsored by the Office of Conservation and Renewable Energy, economic analysis of different lighting options is currently being conducted by Lawrence Berkeley Laboratory. Results from this report may be linked to that work.

Introduction

Lighting represents an important opportunity for energy conservation in the commercial sector. The EIA's service report in support of the National Energy Strategy[7] estimates lighting at 1.0 quadrillion Btu, 22 percent of all energy delivered to commercial buildings in 1990, 39 percent of commercial buildings' electricity consumption. The Electric Power Research Institute (EPRI),[4] starting from similar sources, estimates lighting as 41 percent of commercial electricity. Others (e.g., Goldstein and Watson[10]) have estimated lighting at well over half of commercial electricity use. Piette et al.[15] estimate commercial lighting as 0.9 quadrillion Btu.

The current availability in the marketplace of a wide variety of energy-efficient lighting technologies makes substantial efficiency gains a realistic possibility in the commercial sector. DOE initiatives focus on the potential for commercial lighting conservation from many angles. The Federal Energy Management Program relamping initiative is designed to reduce lighting energy use in federal buildings. Technology transfer programs are aimed at increasing the penetration of existing energy-efficient lighting technology. The Integrated Resource Planning Program is initiating its Database for Energy-Efficient Programs (DEEP) with a study on commercial lighting program experience. Commercial lighting guidelines are also under consideration.

Outside the DOE, the Environmental Protection Agency's Green Lights program promotes energy-efficient lighting as a means to reducing environmental emissions associated with electricity production. Utility Demand-Side Management programs are increasingly looking to commercial lighting as a prime opportunity. These activities create a growing need for understanding the factors that drive commercial lighting requirements, and the potential energy savings that could be achieved through improved commercial lighting efficiency.

This report brings together information from several sources on commercial lighting energy consumption and practice. The analysis has two objectives. The first is to provide a statistical profile of the commercial building stock with respect to factors that determine energy consumption for lighting. The second is to illustrate the use of this profile as a basis for estimating the potential savings in commercial lighting energy under various assumptions. In addressing each of these two goals, the emphasis is on developing a framework for analysis that can be used with additional or alternate assumptions. Thus, the specific estimates presented for energy measures and energy savings are more illustrative than conclusive.

The point of reference for this analysis is the Commercial Buildings Energy Consumption Survey (CBECS). The CBECS collects detailed data on the structure, equipment, use, and energy consumption for a nationally representative sample of commercial buildings. This survey is the only comprehensive source of national-level data on energy-related characteristics of commercial buildings. The CBECS defines the boundaries of the population considered, and the parameters that are accessible to analysis. In addition, building characteristics from the CBECS provide the basis for attaching technical specification from the engineering literature to the survey data base.

In the next section, "Technical Framework," the key factors described by the statistical profile are introduced and defined. The methodology for developing that profile, and for using it to assess the potential for lighting energy conservation is then described. The data sources used and their limitations are also discussed.

Statistical Profile of Commercial Lighting Energy

With the technical framework established in that section, the analytic results are presented in two major sections. The "Commercial Lighting Energy Profile" addresses the first objective of this study. That is, lighting-related building characteristics are cross-tabulated with basic building characteristics including activity, size, age, and location.

The commercial lighting profile presents statistics not previously published in any CBECS report. Particular emphasis is given to statistics that indicate the joint effect of two or more factors, as opposed to tabulating each individually. The factors examined in combination include the building floorspace, operating hours, percents lighted by different types of equipment, percent lighted off-hours, and presence of various lighting conservation features.

The statistics on combined factors indicate the breadth of information available from the CBECS alone, even without incorporating supplementary information and assumptions from other sources. With the inclusion of the supplementary information, rough estimates are obtained of average illumination levels, lighting power densities, lighting end-use intensity, and lighting energy consumption.

In previous publications based on the CBECS data, the only measures provided of lighting use was the amount of floorspace lighted. The statistical profile developed in this report shows how a subgroup (such as buildings used for a particular activity) can contribute to commercial lighting energy consumption in substantially greater or less proportion than its floorspace alone would indicate. These differences are the result of differences in illumination levels maintained, hours of lighting use, and lighting equipment efficiency.

Health care and lodging buildings, for example, each are estimated to have lighting energy use roughly comparable to that for office buildings, which account for nearly four times as much floorspace. Incandescent light bulbs serve less than one fifth of commercial lighted floorspace, yet are estimated to account for nearly two-fifths of commercial lighting energy use.

Averaging over all building activities, higher lighting energy consumption per square foot is estimated in general for larger buildings, despite the fact that energy-efficient lighting equipment is more common. Countering the effect of the more efficient equipment, activities requiring higher illumination levels and longer operating hours are also more common among larger buildings.

Conservation Potential

In the section on "Lighting Energy Conservation Potential," the lighting energy profile provides the framework for estimating the effect of adopting certain technologies or practices on commercial lighting energy consumption. Estimates are presented under varying sets of assumptions. Both the framework for savings estimation and the data inputs could be expanded or refined to incorporate greater detail and accuracy, or to reflect alternate assumptions.

The results indicate that substantial savings are possible using existing energy-efficient lighting technologies, even under modest assumptions as to the effectiveness of the efficient equipment. Under more optimistic assumptions, including the possibility of reducing illumination levels without loss of amenities, dramatic energy savings are possible.

Economic variables are not considered in the statistical profile or savings analysis presented here. The monetary costs and savings are not estimated for the various changes considered in lighting practices. These changes are evaluated strictly in terms of the energy impact should they be adopted. No explicit estimate is attempted as to which of these possible changes are likely, practical, or desirable. It is anticipated that the analysis presented here can be used in conjunction with other studies that examine these issues.